

Coair paper 1/2/11/03

2001057100

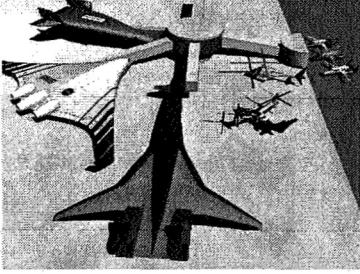
529152

1/5/6

Aviation System Technology Advanced Research Program - AvSTAR

AvSTAR

September 21, 2000



Dr. Dallas G. Denery
Deputy, Aviation Systems Division
Ames Research Center

Aviation System Technology Advanced Research Program - AvSTAR

Planning Team

Chair: Dallas G. Denery (ARC)

Core Planning Team: W. Bryant (LaRC), J. Shin (GRC), T. Edwards (ARC), T. Allard (ARC), H. Erzberger (ARC), K. Roth (ARC), H. Schlickenmaier (HQ), H. McLaurin (FAA)

Associates:

ARC:

S. Atkins, T. Davis, B. Sridhar, S. Green, K. Bilimoria, R. Remington, Y. Gawdiak, Jon Guice, J. Zuk

LaRC:

K. Willshire, S. Johnson, D. Hinton

GRC:

D. Ponchak, Bob Kerczewski

FAA:

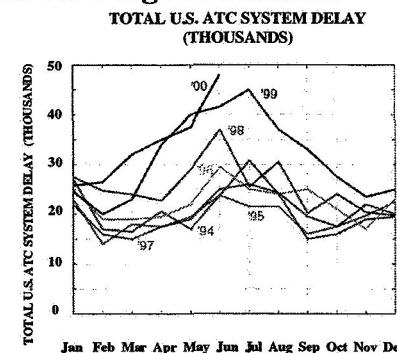
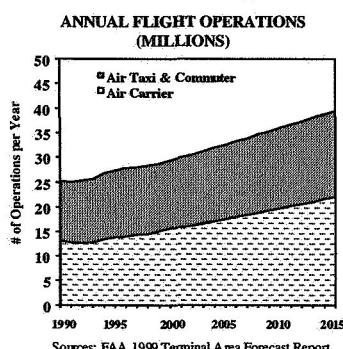
W. Mackenzie, S. Bradford, B. Sanford, J. Recstad, T. Proeschel, S. Pansky, G. Green, S. Moore, G. Kulesa, J. Merkle, D. Ford, C. Rapport

Background

Air transportation delays/congestion continue to grow

- Airline traffic is predicted to grow at 4.3%/year
 - Significant increase in number of delays at busy airports
 - Increasing number of secondary airports experiencing major delays
 - Airspace congestion increasingly becoming major contributor to schedule reliability
- E-commerce, escalating value of property in major commerce centers, search for improved quality of life
 - Major expansion of air traffic services at smaller airports
 - Airspace congestion will become dominant

Air Transportation, on the Verge of Gridlock



Demand is escalating faster than the general economic growth

Delays are soaring and passenger rage is skyrocketing

"Washington, we have a problem"

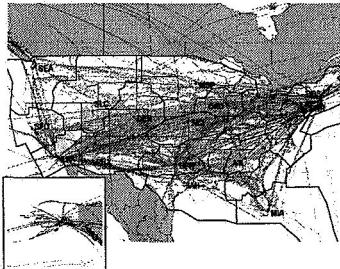
Source: Avoiding Aviation Gridlock: A Consensus for Change, National Civil Aviation Review Commission, Sept 10, 1997, N. Mineta, Chair

Aviation System Technology Advanced Research Program - AvSTAR

Constraining Factors on Today's Air Transportation System

Today's System

- Over 2000 sectors -
- 18,000 ATC personnel -
- Limited runway construction -



- Inability to further reduce separations between aircraft
 - Technology limitations
 - Human limitations
 - Sectorization of airspace has reached its limit
- Inability to make best use of available information to optimize traffic flow

Aviation System Technology Advanced Research Program - AvSTAR

The Problem and Solution Options

Without new technology the results are unacceptable

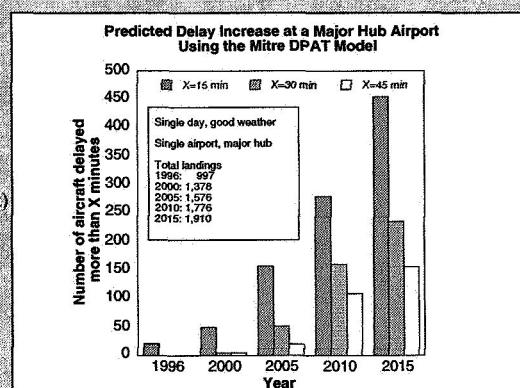
Maintain Current Capabilities (System on Verge of Gridlock)

- Restrict Growth
- Expand Hours of Operation
- Open New Airfields
(This will lead to increased airspace congestion)

Insert New Technologies within Current Paradigm - Tomorrow's System (free-flight)

- FFP1, FFP2, & FFP3
- (Provides Relief Over Next 10-12 Years)

A Revolutionary Change in Airspace Operations- The Future System (The only real solution for the long-term)

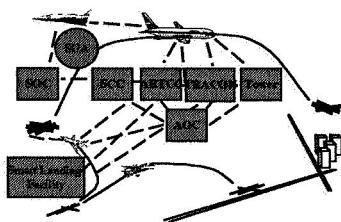


Aviation System Technology Advanced Research Program - AvSTAR

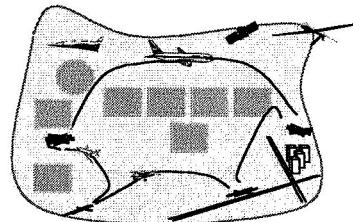
Air Transportation Vision

Seamless operations for all vehicle classes across all airspace to provide vast increases in movement of people/cargo through

- integrated airspace operations
- sharing of information from distributed sources including weather
- advanced automation
- human interactive system monitoring and goal setting capabilities



Today's ATM System
Distinct facilities/segregated airspace
- Procedure based coordination
across facility/airspace boundaries -



The Future Air Transportation System
Unified
- Seamless operations for all vehicle classes
across all airspace -

Aviation System Technology Advanced Research Program - AvSTAR

The Status

Tomorrow's Air Transportation System definition is clear ("Free Flight") and is supported by all constituents

- First implementation has started (NASA products = TMA, pFAST and SMA)
- BUT, significant R&D required to complete Goal/Vision
- The Free-Flight Program will not solve the long-term problem

The Future Air Transportation System is still notional

- *No one* is conducting the research to support the far-term concepts, technologies and methods

The capability required for evaluating future concepts at the requisite degree needs to be available

Aviation System Technology Advanced Research Program - AvSTAR

Program Goals and Objectives

Objectives:

Provide the research and development by 2007 necessary to:

- Complete the development of technology for tomorrow (Free-Flight)
- Provide the foundations for setting the direction for the future (Beyond Free-Flight)

Goals (Air transportation as one component of a fully integrated multi-modal transportation system):

Tomorrow's Air Transportation System*

- 20% increase in throughput at high density airports
- 25% reduction in today's missed/canceled flights due to traffic problems

The Future Air Transportation System*

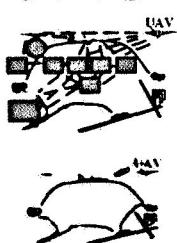
- 3X increase in throughput at high density airports
- 50% reduction in rate of missed/canceled flight

* Systems studies have been initiated to validate goals against program elements

Aviation System Technology Advanced Research Program - AvSTAR

The Program

Program Integration



System-Level Operations Concepts

Tomorrow's ATM Vision

- Align with FAA/Industry
- Concept of Operations

The Future Air Transportation Vision

- Coordinate with FAA and industry
- Functional definition
- Architectural implications
- Interfaces with local transportation

System-Level Simulation

Tomorrow's ATM System - Technologies for Tomorrow



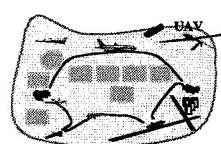
- Surface congestion alleviation
- Runway productivity technologies
- Technology enhanced arrival/departure decision support tools
- Integrated airspace decision support tools
- National traffic flow management
- Runway Independent Aircraft operations
- ATM/TFM weather

Full vehicle-class coverage

Future Air Transportation System - Foundations for the future

System Level Definition

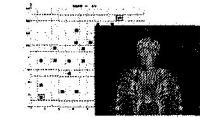
- ATM system level definition/design
- Design for integrity/reliability/graceful degradation



Breakthrough Concepts

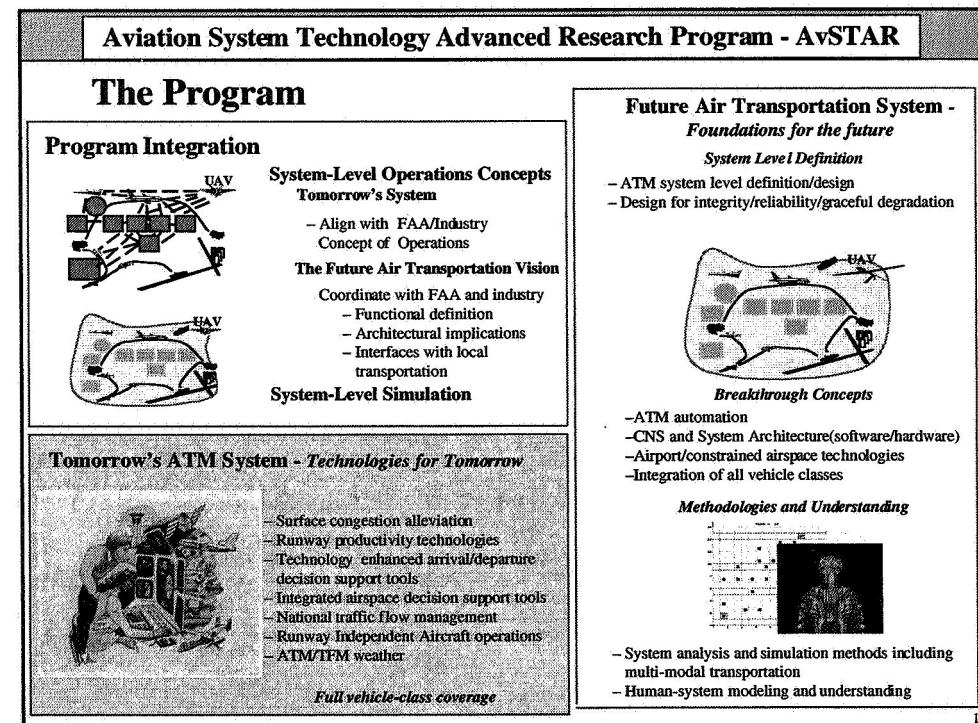
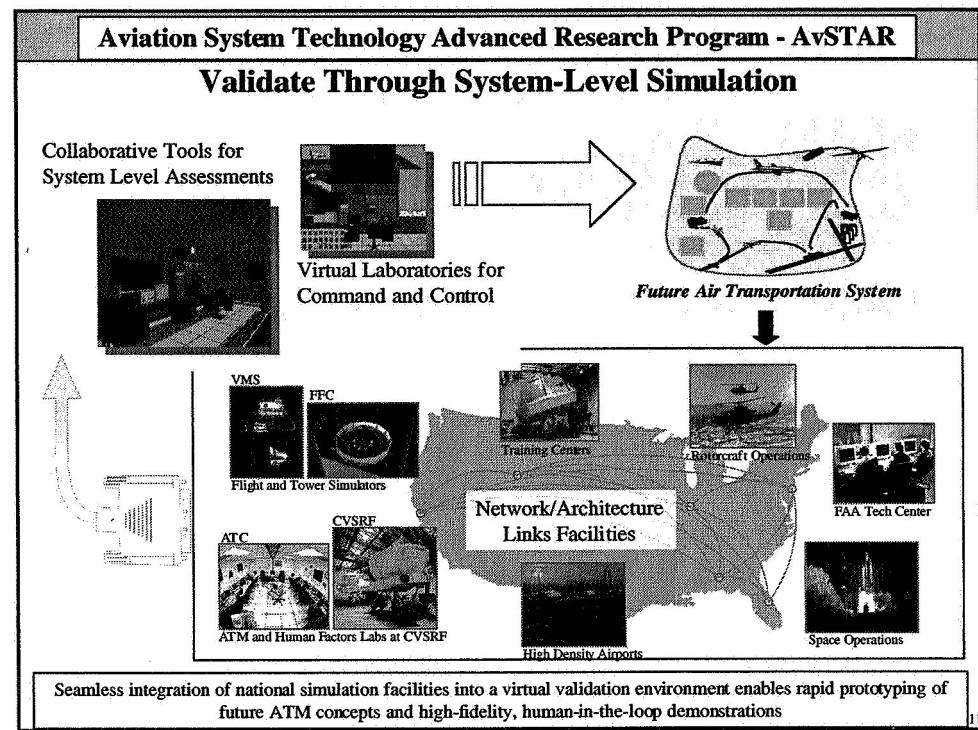
- ATM automation
- CNS and System Architecture(software/hardware)
- Airport/constrained airspace technologies
- Integration of all vehicle classes

Methodologies and Understanding



- System analysis and simulation methods including multi-modal transportation
- Human-system modeling and understanding

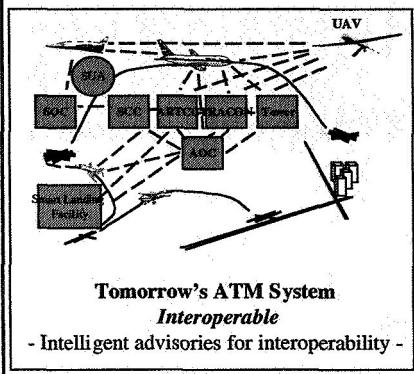
10



Aviation System Technology Advanced Research Program - AvSTAR

Tomorrow's Air Transportation System

Defined in FAA/RTCA Concept of Operations



Technology Challenges

Improved traffic flow management predictions and decision making

- Collaboration between users and computer assisted re-routing
- Improved prediction of traffic patterns and weather

Remove restrictions across facility/sector boundaries

- Introduction of decision support tools such as CTAS integrated with weather for dynamic re-routing

Reduce separation requirements in the terminal area

- Monitoring of trailing vortices
- Technologies for relative positioning of aircraft

Eliminate surface congestion

- Sharing of information on arrivals, departures, gate status
- Taxi guidance
- Intelligent decision making/cueing to eliminate runway incursions
- Optimized taxiway/runway designs/improvements

13

Aviation System Technology Advanced Research Program - AvSTAR

Tomorrow's Air Transportation System (The Program)

Improved predictions and decision making

Remove restrictions across facility/sector boundaries

Reduce separation in the terminal area

Integrated Airspace Decision Support Tools

National Traffic Flow Management

Eliminate surface congestion

Arrival/Departure Decision Support Tools

Integrated Airspace Decision Support Tools

Surface Congestion Alleviation

Runway Productivity

Runway Independent Aircraft Operations

ATM/TFM Weather Integration

Aviation System Technology Advanced Research Program - AvSTAR

Surface Congestion Alleviation

Objective

Airport congestion is rapidly becoming the limiting factor in airport throughput. Incidents of runway incursion in today's system are threatening current airport throughput. Develop traffic management automation, and required technologies, to alleviate surface congestion.

Activities

- Develop & field test near-term advances (early deliverables). Initiate joint activity as a team member in identifying and developing procedures to safely reduce runway/taxiway congestion, making use of the Future Flight Central tower simulator.
- Develop technologies to enable automation aids that will alleviate runway congestion in IMC and VMC while eliminating runway incursions. Investigate solutions that require more substantial changes in the NAS including integration of arrivals, departures and surface operations (field tests toward end of project).

Benefits

- Increased airport throughput (by coordinating taxi occupancy of runways with arrivals & departures)
- Reduced taxi delays (due to queuing for active runway crossings)
- Increased taxi route conformance
- Reduced controller and pilot workloads



Issues

Procedures for "holding short" and "crossing active runways" need to be improved and integrated with an overall surface management strategy to provide improved airport throughput.

- Predictive algorithms to plan runway occupancy (arrivals, departures, and crossings)
- Advisories and displays for controllers and pilots
- Supporting procedures
- Employ datalink to connect flight deck and ATC tower
- Integrated with arrival and departure tools

15

Aviation System Technology Advanced Research Program - AvSTAR

Runway Productivity

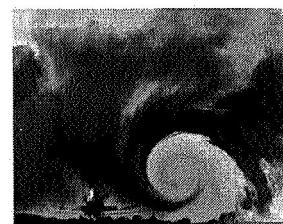
Objectives:

Develop and test new aircraft and sensor technologies and associated procedures including safety assurance information/assessments for increased capacity within the terminal area

Activities:

Building on AVOSS and AILS, develop technologies and procedures critical to achieving increased capacity

- **Develop aircraft technologies for closely spaced parallel/converging runway approaches**
Advanced traffic alerting/detection and avoidance systems and pilot interface devices using high update surveillance capabilities integrated with digital terrain/TERPS databases and traffic information
- **Wake vortex sensor technology**
Develop and evaluate wake vortex sensor system technology for arrivals to parallel/converging runways and departures in operational environment



Key Issues:

Parallel/converging runways

- Design for reliability/robustness
- Interaction with other traffic in the event of an alert
- Integration of mixed equipage
- Shared picture between ground and air

Wake Vortex

- Stability of vortex predictions
- Reliability of predictive vortex decay modeling
- Procedures for integrating into routine operations
 - Clear/concise information
- Vortex sensor placement

16

Aviation System Technology Advanced Research Program - AvSTAR

Technology Enhanced Arrival/Departure Decision Support Tools

Objectives:

Optimize throughput through the introduction of new technologies and the maturation of emerging technologies.

Activities:

Terminal arrival/departure/surface planning advisory system

Building on CTAS, SMS, existing tower capabilities and advances in data-link, weather and vortex sensing technologies, develop and demonstrate interdependent arrival, departure, and surface tools to maximize throughput

- Dynamic spacing/routing based on weather/vortex

Accelerate aFAST and enhance to include weather/vortex constraints/opportunities for dramatic increase in capacity while maintaining safety

- Expedite departure path planner (EDP)

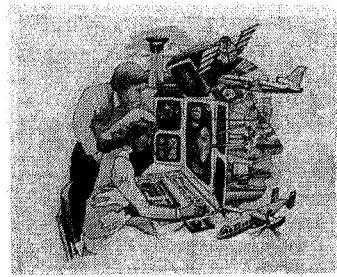
Develop path planning tools that are compatible with FAST to aid the controller in safely merging departure traffic into en route streams

- Environmentally compatible operations

Enhance FAST and EDP with capabilities to support reduced noise arrival and climb-out routes

- Interdependent arrival/surface advisory system

Develop the automation to assist in airport-centric flow control for interdependent arrivals and departures



Key Issues:

- Human/DST interaction for safety of operations
- Design for robustness
- Integration of mixed equipage
- Air/ground integration via data-link

17

Aviation System Technology Advanced Research Program - AvSTAR

Integrated Airspace Decision Support Tools

Objectives:

Develop flight deck and ground technologies aimed at removal or reduction of restrictions through collaboration between regional/local traffic management coordinators, sector controllers, airline operations center personnel, and flight crew

Activities

Time-based scheduling for regional/local traffic flow management

- Constrained Airspace Tool

Assist TMC's in making flow changes in congested sectors by techniques such as dynamic re-sectorization, re-routing, and metering

- Regional Metering Tool

Distribute metering delays to Centers upstream of the flow constraint problem

Controller advisory tools for achieving flow conformance

- En route Spacing Tool

Assist sector controllers trial-plan and execute conflict-free flight deck compatible trajectories that efficiently conform to spacing restrictions

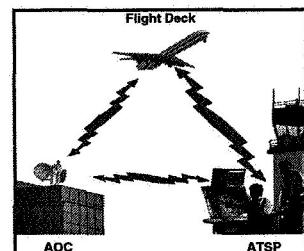
- En route Descent Advisor

Advise sector controllers on how to achieve conflict-free flow-rate conformance to spacing restrictions or metering times that are flight-deck compatible.

- Direct-To Tool integrated with TFM tools

Ensure compliance of Direct-To advisories with downstream TFM constraints ATC/AOC/Flight Deck Integration

- Facilitate collaboration between AOC, local flow control, sector controllers and flight deck as a function of equipage (FMS, data-link)



Key Issues:

- Affecting flights to meet flow rate in a way that minimizes impact on AOC and is compatible with aircraft performance and crew procedures
- Mixed equipage
- Integration with complementary decision support tools for CDM and en route flow control being developed by FAA and companion organizations

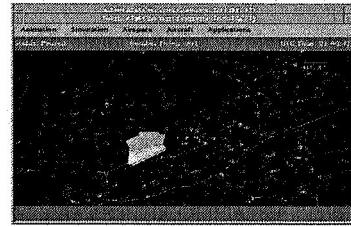
18

Aviation System Technology Advanced Research Program - AvSTAR

National Traffic Flow Management

Objectives:

Develop technologies for planning NAS-wide TFM initiatives through collaboration between system command center managers, regional/local traffic management coordinators, and flight operations center personnel.



Activities:

- **Traffic Flow Automation System**

TFAS will run multiple instances of CTAS to create a 'National' CTAS functionality. TFAS will provide aircraft prediction data to the FAA System Command Center's Enhanced Traffic Management System (ETMS) to increase the reliability of ETMS Sector-Overloading and Monitor-Alert tools.

- **System-level Traffic Re-routing Tool**

Automation to assist SCC managers collaborate with AOC personnel to balance airspace demand across the NAS by implementing an appropriate mix of traffic re-routing and ground delays at the national level.

- **National Traffic Flow System Analysis/Assessment**

Assess performance of National Traffic Flow to identify primary factors that lead to delay, errant rerouting, effective strategies

Key Issues:

- Accuracy in predicting traffic flows in actual operations given fidelity in weather, aircraft performance and intent information
- Optimizing system-level performance while allowing airspace users to manage their fleet
- Shared awareness between all parties
- Integration of weather prediction capabilities
- Integration with complementary decision support tools for CDM and National Traffic Flow Management being developed by FAA and companion organizations

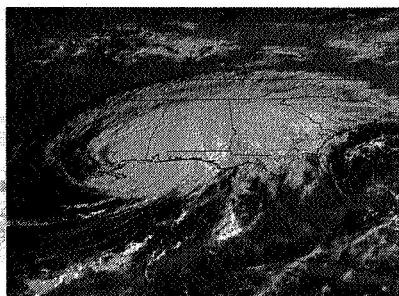
19

Aviation System Technology Advanced Research Program - AvSTAR

ATM / TFM Weather Research

Objective:

Develop requirements for weather products tailored towards ATM/TFM applications and invest in existing mid/long-term weather research to develop these products and integrate with ATM Decision Support Tools.



Activities:

- **The ATM Meteorology Research Team**

NASA will form a small interdisciplinary team that bridges the gap between the ATM/TFM and meteorology communities. This team will identify, instigate and coordinate cooperative weather research that serves ATM/TFM weather information needs. By utilizing small, targeted research investments, innovative solutions can be developed for a wide variety of ATM/TFM prediction needs. Potential research includes:

- Definition of ATM/TFM Relevant Weather Information
- Validation ATM/TFM Weather Predictions
- Development of Prediction Probability/Uncertainty Models for ATM Application

User Deviation Probability & Impact Assessment/estimation of pilot willingness to penetrate bad weather and the impact on traffic flows.

Key Issues:

Enables Revolutionary Advances

By utilizing expert knowledge in both ATM and meteorology, new and innovative solutions can be identified and developed.

Highly Leveraged Investment

NASA can steer or expand the scope of research performed in the meteorology community to address ATM needs for a fraction of the cost of doing in-house research. (A strategy successfully used by NASA's "Wind Research Team.")

20

Aviation System Technology Advanced Research Program - AvSTAR

Runway Independent Aircraft Operations

Objectives:

- Develop technologies & criteria database that will:
 - Enable simultaneous non-interfering (SNI) A/C ops
 - Allow V/STOL aircraft to operate at airports under Cat IIIA
 - Establish ops requirements for future powered lift A/C



Activities:

- SNI Criteria Database Development
 - Ops Concept
 - Adverse weather / low noise ops
- ATM / Aircraft Systems Integration
 - Human Centered Cockpit
 - ATM tools
- V/STOL A/C Performance / Airspace Requirements Database
- Demonstrations

Key Issues:

- Air & and infrastructure requirements
- Level I handling qualities
- Non-interfering missed approaches & guided departures
- Low noise flight paths
- SNI ops concept acceptance

Benefits:

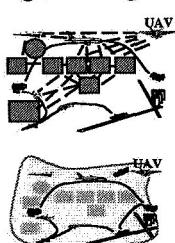
- Air traffic growth without enlarging airports
- Aviation System throughput increase & delay reduction
- Airspace safety & reliability improvement
 - Vehicles use unused & underutilized space
- National mobility & accessibility increased

21

Aviation System Technology Advanced Research Program - AvSTAR

The Program

Program Integration



System-Level Operations Concepts Tomorrow's System

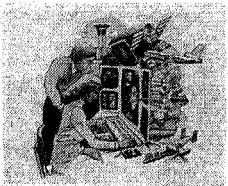
- Align with FAA/Industry Concept of Operations

The Future Air Transportation Vision

- Coordinate with FAA and industry
 - Functional definition
 - Architectural implications
 - Interfaces with local transportation

System-Level Simulation

Tomorrow's ATM System - Technologies for Tomorrow



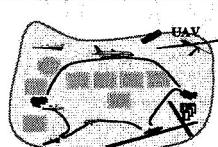
- Surface congestion alleviation
- Runway productivity technologies
- Technology enhanced arrival/departure decision support tools
- Integrated airspace decision support tools
- National traffic flow management
- Runway Independent Aircraft operations
- ATM/TFM weather

Full vehicle-class coverage

Future Air Transportation System - Foundations for the future

System Level Definition

- ATM system level definition/design
- Design for integrity/reliability/graceful degradation



Candidate Breakthrough Concepts

- ATM automation
- CNS and System Architecture(software/hardware)
- Airport/constrained airspace technologies
- Integration of all vehicle classes

Methodologies and Understanding



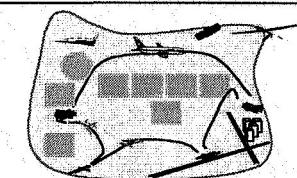
- System analysis and simulation methods including multi-modal transportation
- Human-system modeling and understanding

22

Aviation System Technology Advanced Research Program - AvSTAR

The Future Air Transportation System

Notional - Concept of Operations Does not Exist



The Future Air Transportation System Unified

- Seamless operations for all vehicle classes across all airspace -

System Level Definition

- Functions, architecture, interfaces with local transportation
- Design to allow for sub-system failure
 - Levels of automation for system planning/separation assurance
 - Ground based
 - Airborne based
- Transition from today
- Validate through system level simulation

Technology Challenges

Candidate Breakthrough Concepts

- ATM automation
 - Eliminate sector-based control of traffic
 - Elevate controller to system-level manager
 - Remove controller from tactical control of traffic
 - Automated conflict detection and resolution
- Real-time system - wide optimization
 - Probabilistic decision making
 - Integration of airspace resources
 - Planning over continuum of time horizons
 - Human interactive model-based monitoring and goal setting
- New technologies for quantum leaps in capacity/throughput
 - Airports
 - Weather

Infrastructure concepts

Full vehicle class coverage

Methodologies and Understanding

- Systems analysis and simulation methods
- Human System Modeling and Understanding

The Enablers

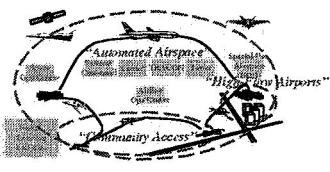
- Tomorrow's technologies provide the building blocks
- Information systems technologies provide the mortar
 - (Automated reasoning, human centered computing, intelligent data understanding, revolutionary computing)

23

Aviation System Technology Advanced Research Program - AvSTAR

The Future Air Transportation System (The Program)

System Level Definition



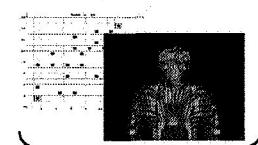
Functions, architecture, interface with local transportation

Design to allow sub-system failure

Transition from today

Validate through system level simulation

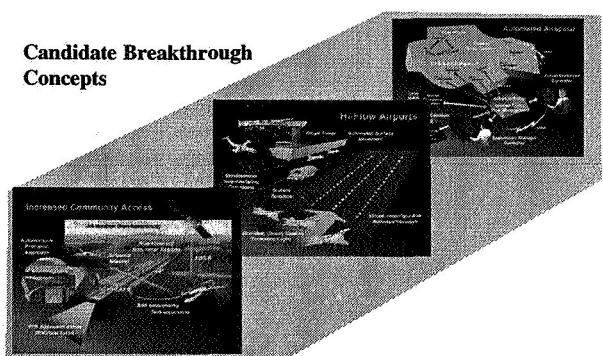
Methodologies and Understanding



Systems modeling/analysis and simulation

Human modeling and understanding

Candidate Breakthrough Concepts



ATM automation

- Super-sector
- Real-time system wide optimization
- Interactive model-based monitoring and goal setting

Quantum leaps in capacity/throughput

Infrastructure concepts

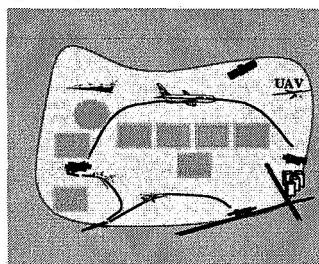
Full vehicle class coverage

24

Aviation System Technology Advanced Research Program - AvSTAR

The Future Air Transportation System

System-level Definition



Key Issues:

- Very complex and heterogeneous environment to visualize
- Very difficult task to build a consensus
- System level modeling lacks credibility
- Implications on the human operator of novel approaches is difficult to assess

Objective:

Identify and assess overall operations concepts/system designs for Unified Airspace System and integrate with concepts from the elements.

Activities:

- ATM System Level Definition/Design
 - Identify and further develop system-level operations concepts
 - Define overall architectural designs satisfying the operational concepts
 - Assess candidate operations concepts through systems analysis and modeling
 - Define interfaces with other transportation entities
- Design for reliability/integrity/ graceful degradation
 - Conduct failure modes and effect analysis
 - Investigate model-based reasoning tools and other methods for system monitoring/warning
 - Conduct analysis and simulation to validate system robustness to failure
- Transition from today
- Validation with high-fidelity, human-in-the-loop simulation

25

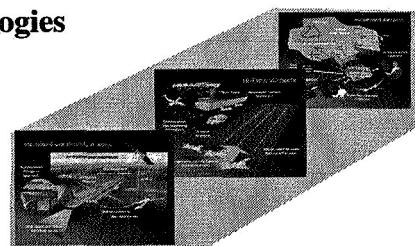
Aviation System Technology Advanced Research Program - AvSTAR

The Future Air Transportation System

Breakthrough Concepts & Technologies

Objective:

Conduct exploratory research to identify novel concepts and technologies for enabling the unified airspace vision



Activities (Candidates):

- **ATM Automation Concepts**
 - Real-time system wide optimization
 - Eliminate sector-based control of traffic
 - Elevate controller to system-level manager
 - Automated conflict detection and resolution
 - Human interactive model-based monitoring and goal setting
- **New technologies for capacity/throughput**
 - Airports
 - Weather
- **Infrastructure Concepts**
 - CNS technologies
 - Architecture/software
- **Integration with all Vehicle Classes**
(Space operations, unmanned air vehicles)

Key Issues:

- Acceptance of major paradigm shifts
- Modeling benefits and safety of revolutionary concepts
- Future vision continually changes with new technologies and societal needs
- Transition path to implement revolutionary changes

26

Aviation System Technology Advanced Research Program - AvSTAR

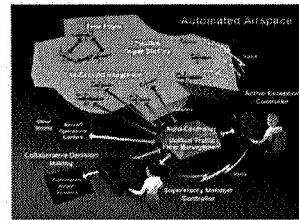
ATM Automation Concepts

Objective:

Develop advanced ATM concepts and human automation technologies to enable major increases in the NAS capacity

Activities:

- Real-time system-wide optimization
 - Innovative ATM processes to meet real-time market demand
 - Integrated planning across all the NAS timetframes
- Eliminate sector-based control of traffic
 - Automated aircraft separation while meeting flow control constraints
- Interactive model-based monitoring and goal setting
 - Human role in direction of automated ATM/C systems
 - Monitoring state of automated systems



Key Issues:

- Human role in automated systems
- Reliability, robustness and failure handling of automated systems

27

Aviation System Technology Advanced Research Program - AvSTAR

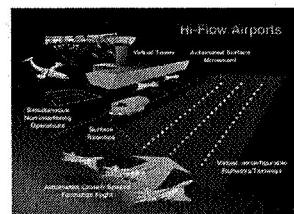
Quantum Leaps in Capacity/Throughput

Objective

Develop advanced concepts and technologies to enable quantum leaps in throughput at airports and in enroute weather

Activities

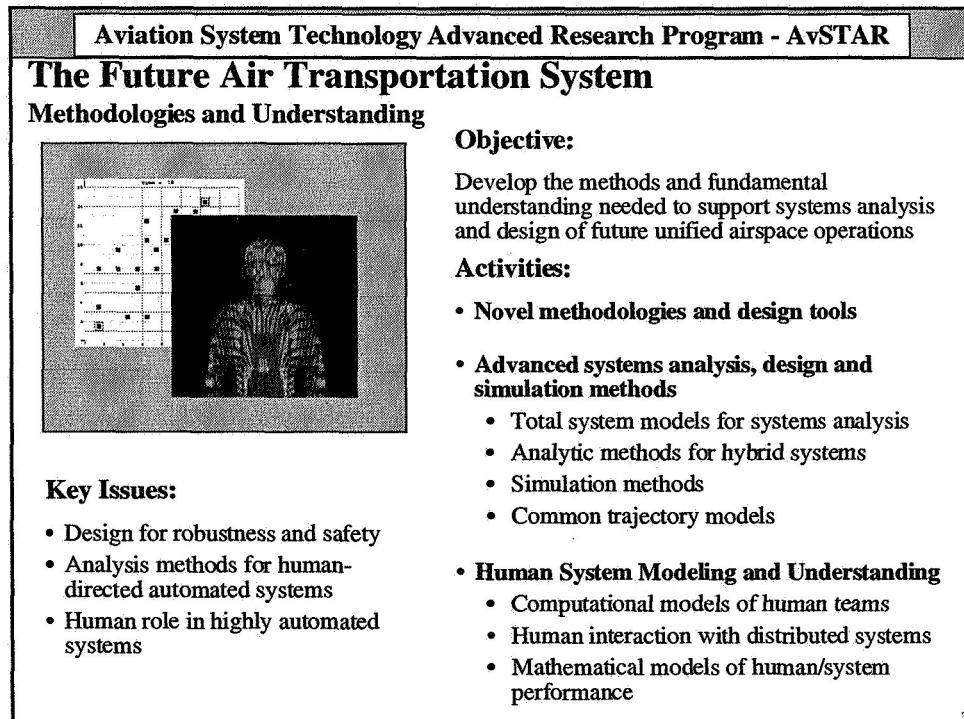
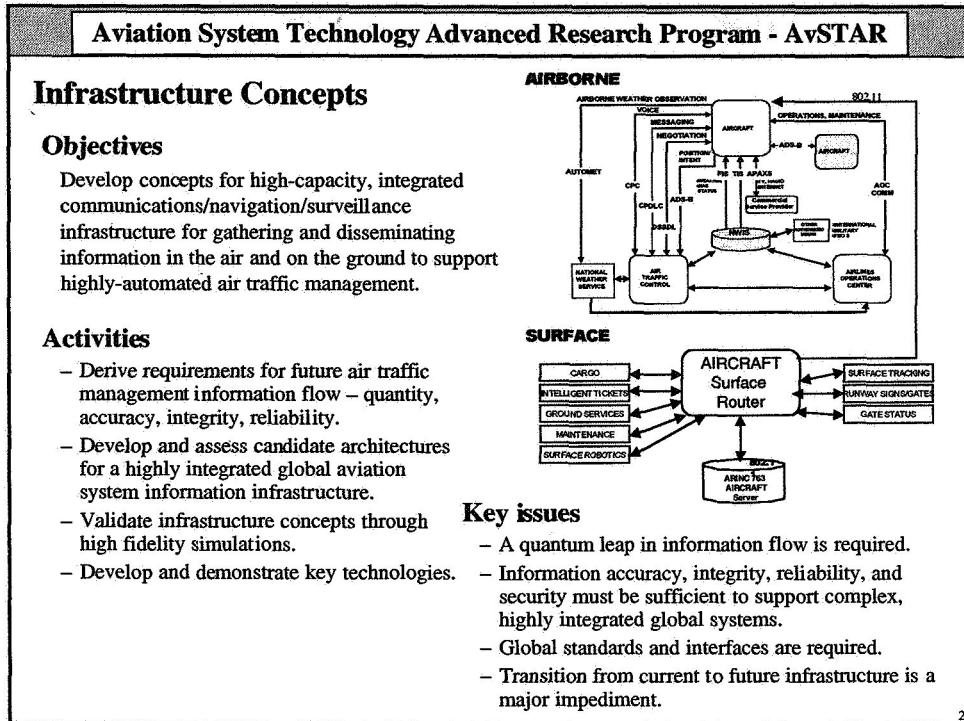
- **Airport Operations**
 - Meta-airport operations
 - Closely spaced aircraft take-off and landing
 - Dynamically reconfigurable runway location
 - Automated zero-visibility surface movement
 - Dynamic virtual ramp and control towers
 - Airport robotics
 - Non-towered airport automation to support high-density operations
- **Weather Operations**
 - Coupling of weather prediction with ATM:
 - Precise aircraft movement around weather cells in enroute airspace
 - Accurate airport runway/airspace reconfiguration



Key Issues

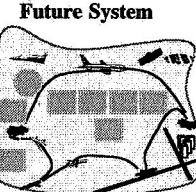
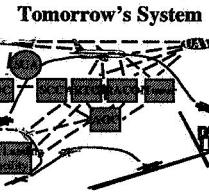
- Accuracy and confidence of weather prediction
- System reliability and safety of closely spaced aircraft operations
- Wake vortex prediction system accuracy and confidence

28



Aviation System Technology Advanced Research Program - AvSTAR

Products



Technologies by 2007 for Tomorrow's System

System-level Integration

- Improved National Flow Control
 - Traffic Flow Automation System for system-wide flow predictions
 - User/system automated re-routing tool
 - User compliant local flow control automation
 - Automation for metering in congested airspace
 - Aircraft compatible sector advisories
 - Collaborative ACC, Flight deck, ATC
 - Weather integration for TFM/ATM

Local Optimization

- Technology-enhanced arrival/departure/surface advisory systems
 - Dynamic spacing/routing
 - Integrated departure/surface operations
 - Surface congestion alleviation
- Wake vortex sensor technology for arrivals and departures
- Technology for approaches to closely spaced parallel and converging runways
- Validation of runway independent operations

Foundations by 2007 for Future System

- Validated set of future ATM concepts
 - Design for safety/graceful degradation
- Tools for analyzing and designing a unified system
 - Systems analysis
 - Performance/safety analysis and design
 - Common trajectory prediction methodology
- Understanding of human attributed/limitations in highly integrated/distributed systems
- Candidate CNS architectural concepts
- Implications of full vehicle-class coverage

- Feasibility established for
 - Use of information technologies for improved airport operations
 - High flow airport concepts
 - Virtual runways/taxi-ways
 - Virtual tower and remote-airport sensor system
 - Smart landing facilities for non-towered airports
 - Airport automation

31

Aviation System Technology Advanced Research Program - AvSTAR

Progression Towards the Future

Aviation System Technology Advanced Research - AvSTAR

- Development of core component technologies for quantum improvements in capacity/throughput and seamless operations across all airspace
 - Development and integration of active air traffic management automation tools with advanced technologies (wake vortex sensor system, ADS-B, weather)
 - Breakthrough air traffic management concepts beyond today's Free-Flight Program
- Development of a virtual airspace simulation environment for testing advanced concepts
- Evaluation of advanced air traffic management concepts

Small Aircraft Transportation System - SATS

- Airborne technologies for revolutionary personalized transportation system to non-towered airports

Aviation Systems Capacity - ASC

- First generation technologies for early capacity increases
 - Passive controller/TMC automation decision aids
- Concept exploration for distributed air/ground traffic management
- Continued support for the FAA's Free-Flight Program

32